IS 11639-3 (1996): Structural design of penstocks - Criteria, Part 3: Specials for penstocks [WRD 14: Water Conductor Systems]

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Indian Standard

STRUCTURAL DESIGN OF PENSTOCK — CRITERIA

PART 3 SPECIALS FOR PENSTOCKS

ICS 23.040; 93.160

BUREAU OF INDIAN STANDARDS
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Price Group 7

Water Conductor System Sectional Committee, RVD 14

FOREWORD

This Indian Standard (Part 3) was adopted by the Bureau of Indian Standards, after the draft finalized by the Water Conductor System Sectional Committee had been approved by the River Valley Division Council.

Different types of specials like bends, reducers, expansion joints, etc are used in steel penstocks carrying water from surge tanks or reservoirs to the power houses. This standard covers the structural design aspects of such specials taking into account the important hydraulic parameters involved. This standard is being published in three parts: Part 1 Surface penstocks, Part 2 Buried / embedded penstock and Part 3 Specials for penstocks.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, should be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

STRUCTURAL DESIGN OF PENSTOCK – CRITERIA

PART 3 SPECIALS FOR PENSTOCKS

1 SCOPE

This standard (Part 3) lays down the criteria for structural design of the following specials used in penstocks:

a) Bends,
b) Reducer pieces,
c) Branch pipes,
d) Expansion joints and dresser couplings,
e) Manholes,
f) Bulk heads,
g) Air vents and air valves, and
h) Other miscellaneous penstock accessories.

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
2825 : 1969	Code for unfixed pressure vessels
11625 : 1986	Criteria for hydraulic design of penstocks
11639 (Part 1) : 1986	Criteria for structural design of penstocks: Part 1 Surface penstocks

3 BENDS

3.1 General

Depending on topography, the alignment of the penstock is often required to be changed, in direction, to obtain the most economical profile so as to avoid excess excavation of foundation strata and also to give it an aesthetic look with the surroundings. These changes in direction are accomplished by curved sections, commonly called penstock bends. For ease of fabrication, the bends are made up of short segments of pipes with mitred ends.

Bends should be made with large radius and small deflection between successive segments in order to minimize the hydraulic loss due to change in direction of flow. It is preferable to provide the radius of bend as 3 to 5 times the diameter of the pipe and the deflection angle between each successive segments as 5 degrees to 10 degrees. For penstocks where conservation of head is very important, deflection angles from 4 degrees to 6 degrees may be used. From the consideration of alignment, penstock bends are generally classified as simple bends, compound bends and reducing bends.

3.2 Simple Bends

When the change of alignment is only in one plane, that is either vertical or horizontal, the bend is called a simple bend and the deflection angle is the deviation in the direction of alignment (*see* Fig. 1A).

3.3 Compound Bends

When the change of alignment is in both the planes, that is vertical as well as horizontal, it is advantageous to accommodate the deflections, in both the planes, by providing a single bend known as a compound bend (*see* Fig. 1B). Usually the plan angle and profile angles are known and it is required to determine the true angle in the plane of the bend and the bend rotations. Some guidance regarding computations and applicable formulae for various situations are given in Annex A. During the installation of bends in the field the bend is to be rotated by a certain angle which is indicated as θ and ϕ in Annex A.

3.4 Reducing Bends

In long and very high head penstocks, it sometimes becomes necessary to decrease the diameter of the pipe as the head increases. In such cases it is advantageous to combine the reduction in diameter with a bend, wherever possible, by providing a reducing bend (*see* Fig. 1C).

For the design of reducer bends the following simplified formulae may be used:

$$D_x = \frac{D_1 - 2\,(x-1)\,R \tan P \sin\theta}{\cos\theta} \quad \ldots\ldots\ldots \text{(i)}$$

$$P = \frac{\Delta}{n} \quad \ldots\ldots\ldots \text{(ii)}$$

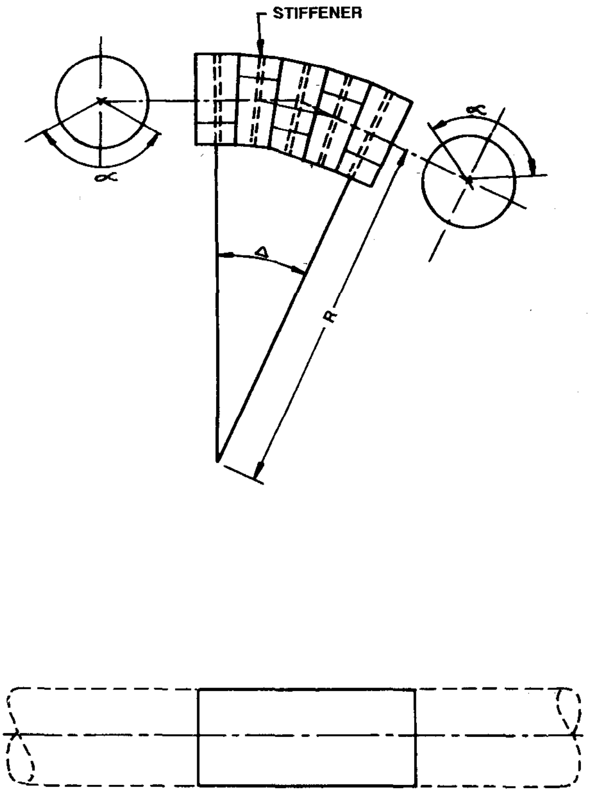
$$\sin\theta = \frac{D_1 - D_n}{2\,(n-2)\,R \tan P} \quad \ldots\ldots\ldots \text{(iii)}$$

$$\tan\phi = \frac{\sin 2P}{\cos 2P + \cos\theta} \quad \ldots\ldots\ldots \text{(iv)}$$

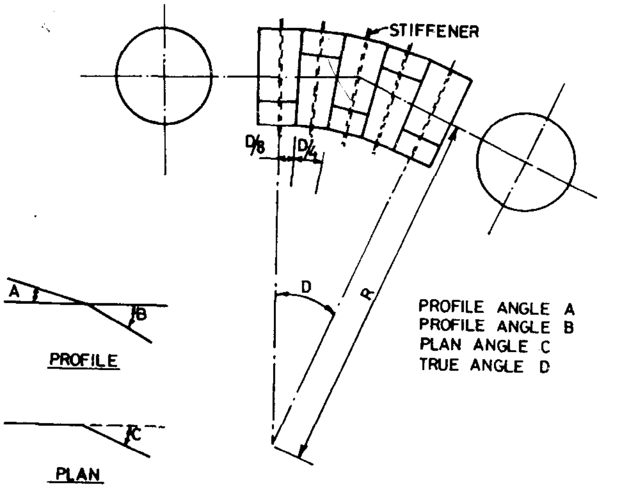
$$Z_1 = \frac{r_1 \sin\theta}{\cos 2P + \cos\theta} \quad \ldots\ldots\ldots \text{(v)}$$

$$Z_n = \frac{r_n \sin\theta}{\cos 2P + \cos\theta} \quad \ldots\ldots\ldots \text{(vi)}$$

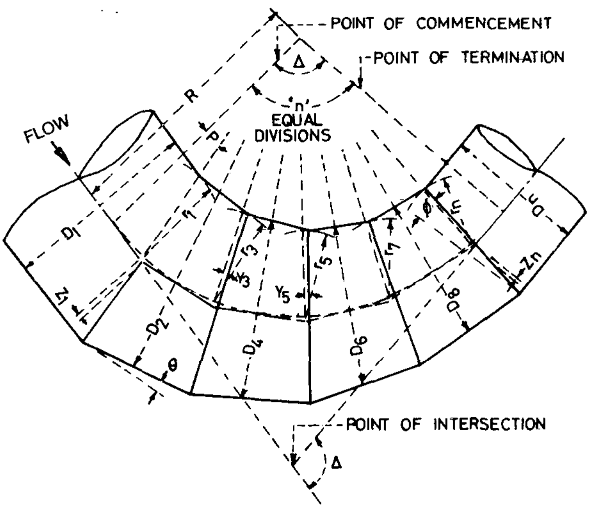
$$Y_x = \frac{r_x \ \text{Sin}\ \theta}{\text{Cos}\ P} \qquad \text{.........(vii)}$$



1A Simple Bend Details



1B Compound Bend



1C Reducing Bend

FIG. 1 TYPE BEND DETAILS

where

- D_x = Inside diameter of pipe at the point under considerations in mm,
- x = Number of divisions from plane Pc to point under considerations,
- R = Radius of bend in mm,
- D_1 = Inside diameter of large pipe in mm,
- n = Number of deflections,
- Δ = Angle of intersection in degrees,
- D_n = Inside diameter of small pipe in mm,
- r_1 = $D_1/2$,
- r_n = $D_n/2$,
- r_x = $r_1 - (x-1) R \tan P \ \text{Sin}\ q$,
- θ = Angle as shown in Fig. 1C in degrees, and
- ϕ = Angle as shown in Fig. 1C in degrees.

4 REDUCER PIECE

4.1 General

In the case of very long penstocks, it is often necessary to reduce the diameter of the pipe as the head on the pipe increases. This reduction from one diameter to another should be effected gradually by introducing a special pipe piece called reducer piece.

4.2 The reducer piece is a frustum of a cone. Normally the angle of convergence should be kept between 5 degrees to 10 degrees so as to minimize the hydraulic loss at the juncture where the diameter is reduced. The

length of reducer pipe may be calculated by the formula:

$$L = \frac{D_1 - D_2}{2 \tan \phi}$$

where

L = Length of reducer pipe in mm,

ϕ = Angle of convergence in degrees, and

D_1 and D_2 = Diameter at the entry and exit respectively in mm.

4.3 The thickness of the reducer piece may be determined using the following formula:

$$t = \frac{PD}{[(2 \text{ Cos } \alpha (\sigma_a . E - 0.6 \, P)] + C}$$

where

P = internal water pressure in N/mm^2,

D = internal diameter of the reducer at the larger end in mm,

α = half apex angle,

σ_a = allowable stress in steel in N/mm^2,

E = lowest efficiency of any joint (*see* IS 2825 : 1969), and

C = corrosion allowance (*see* IS 2825 : 1969).

5 BRANCH PIPE

5.1 General

Depending upon the number of units a single penstock feeds, the penstock branching is defined as bifurcation when feeding two units, trifurcation when feeding three units and manifold when feeding a greater number of units by successive bifurcations. Branch pipes of bifurcating type are generally known as " wye " pieces which may be symmetrical or assymetrical.

5.2 Generally the bifurcating pipe has two symmetric pipes, after the bifurcating joints, and the deflection angle of the branching pipes ranges between 30 degrees to 75 degrees. In order to reduce the head loss, a smaller deflection angle is advantageous. However, the lesser the bifurcating angle, greater the reinforcement required at the bifurcating part. The wye branches should be given special care in design to ensure safety of the assembly under internal pressure of water. The introduction of a bifurcation considerably alters the structural behaviour of the penstock in the vicinity of the branching.

5.3 The hydraulic requirement requires the inlet and outlet velocities equal at full load and the branch pipe transition conical, with elliptical section along the plane of intersection. When one of the pipes is to be sharply in skew to the main pipe, it gives rise to high stress along the junction.

5.4 One method of reinforcing the branches is to provide external girder and stiffener ring with an internal tie-rod (*see* Fig. 2). The deflections of U girder, ring girder and tie-rod due to internal pressure are determined in terms of unknown reaction by strain energy method. Equating these at the point of intersection, unknown reactions are determined and the stresses in these members checked.

5.5 Another method of reinforcing the wye is to provide a single elliptically shaped sickle plate at the plane of intersection. Typical bifurcation with sickle type reinforcement is shown in Fig.3. The practice is more commonly adopted for high head penstock branches. The sections along the bifurcations consist of two intersecting rings with angle (ϕ) varying longitudinally. The rings are interconnected longitudinally by the splitter plate to avoid large deformations and consequent high stresses. The splitter plate is designed to take up the unbalanced loads at the intersection. The splitter section is formed along the intersection plane of the conical branches plane and has the form of an ellipse with semi-major and minor axes.

The introduction of splitter does not materially alter the state of stress in the shell, in symmetrical bifurcations, as the thin walled shells do not resist bending, but carry load by membrane action.

The design of the sickle reinforcement involves:

a) Determining the shape of the sickle to ensure sufficient radial plate width, to keep the resultant reaction exactly at the centre of width of any particular place, and thus obviate eccentricity and its effects; and

b) The thickness of the sickle to keep the stresses within the permissible limits, that is same as stress in shell.

5.6 In the case of unsymmetrical branching, shell stresses are affected to a large extent and additional reinforcement in the form of ring girder is required at the start of the bifurcation to minimize deformation and stresses. The analytical approach for design of ring girder is based on strain energy principle. The deformation of the ring girder determined in terms of the unknown reactions, is equated to that of the splitter plate at the point of intersection. The unknown reactions and stresses are obtained for proportioning of ring girder dimensions. The influence of the ring girder dies down approximately at a length of 0.3 R where R is the radius of the pipe.

5.7 For accurate determination of stress in the shell and reinforcing elements of an unsymmetrical branching, a structural model with strain gauge measurements is required. The structural model is helpful for evolving a safe and economic design.

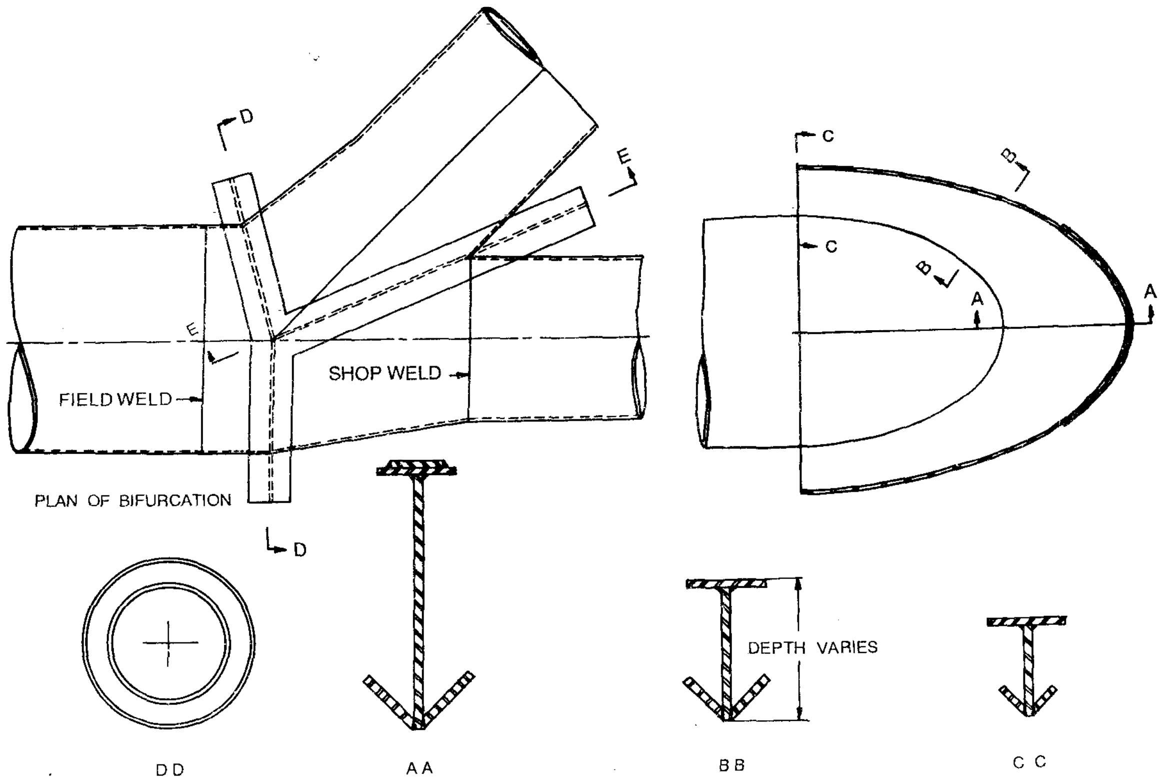


FIG. 2 DETAILS OF BIFURCATION TYPE WYE PIECE WITH EXTERNAL REINFORCEMENT

5.8 The third type of pipe branching is in the form of a spherical shell enclosing the bifurcation point. In this case, in order to reduce the water head loss, resulting from the suddenly increased inner volume at the spherical part, flow rectifying plates are provided inside the spherical shell.

5.9 Hydraulic aspects of the head losses for different types of branches are described in IS 11625 : 1986.

6 EXPANSION JOINTS AND DRESSER COUPLINGS

6.1 General

Expansion joints are installed in exposed penstocks between fixed point or anchors to permit longitudinal expansion, or contraction when changes in temperature occur and to permit slight rotation when conduits pass through two structures where differential settlement or deflection is anticipated. The expansion joints are located in between two anchor blocks generally downstream of uphill anchor block. This facilitates easy erection of pipes on steep slopes.

6.2 Expansion joints should have sufficient strength and water tightness and should be constructed so as to satisfactorily perform their function against longitudinal expansion and contraction. The range of variations to be used for calculation of expanded or contracted length of penstocks should be determined keeping in consideration the maximum and minimum temperature of the erection sites.

6.3 Depending upon the internal pressure, diameter of pipe and magnitude of movement expected, the following types of expansion joints are used for penstocks:

a) Sleeve type expansion joint, and

b) Bellows type expansion joint.

6.3.1 For large diameter fabricated steel pipe, sleeve type expansion joint is generally used. In this type, the longitudinal movement of the pipe is permitted by the provision f two closely fitting sleeves, the outer sleeve sliding over the inner sleeve. To prevent leakage, packing rings are provided between the sleeves within a stuffing box and held by a retainer ring and packing glands with bolts. The outer surface of the inner sleeve is usually given a stainless steel/nickel cladding to prevent corrosion and reduce friction to facilitate easy movement of the joint. The gland bolts press the gland inside the space between the inner and outer sleeves against the packing material consisting of lubricated flax which is retained by an inner ring. Typical details of a sleeve type expansion joint are shown in Fig. 4 A.

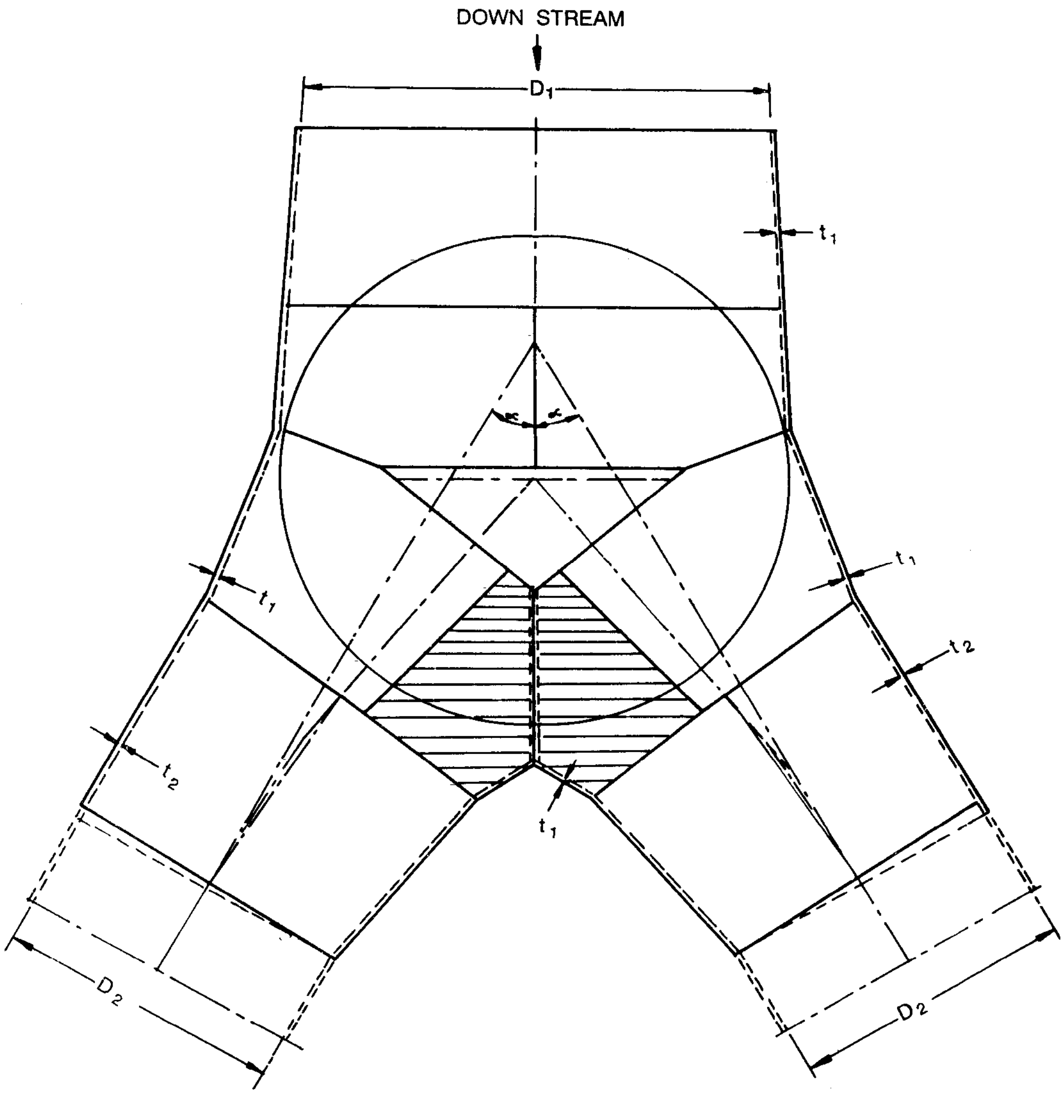


FIG.3 TYPICAL BIFURCATION WITH INTERNAL REINFORCEMENT

Fig. 4 B shows a special double sleeve type of expansion joint provided with two stuffing boxes and packing glands. This is more flexible to permit longitudinal as well as transverse deflection.

6.3.1.1 *Design of gland bolt*

The bolt is designed to exert enough pressure on the packing so that 1.25 to 1.5 times the internal hydrostatic pressure is mobilised between the sleeves and the packing. The value of Poisson's ratio may be taken as 0.3 for flax and 0.5 for rubber. The inner sleeve is designed to resist the external pressure P_2 exerted on it by packing due to bolt force, transferred through the gland. The following formulae may be used in the design of gland bolt :

$$P_2 \geq 1.25 \text{ to } 1.5\,P \qquad \text{......... (ix)}$$

$$P_2 = \frac{P_1\,\mu}{(1-\mu)} \qquad \text{......... (x)}$$

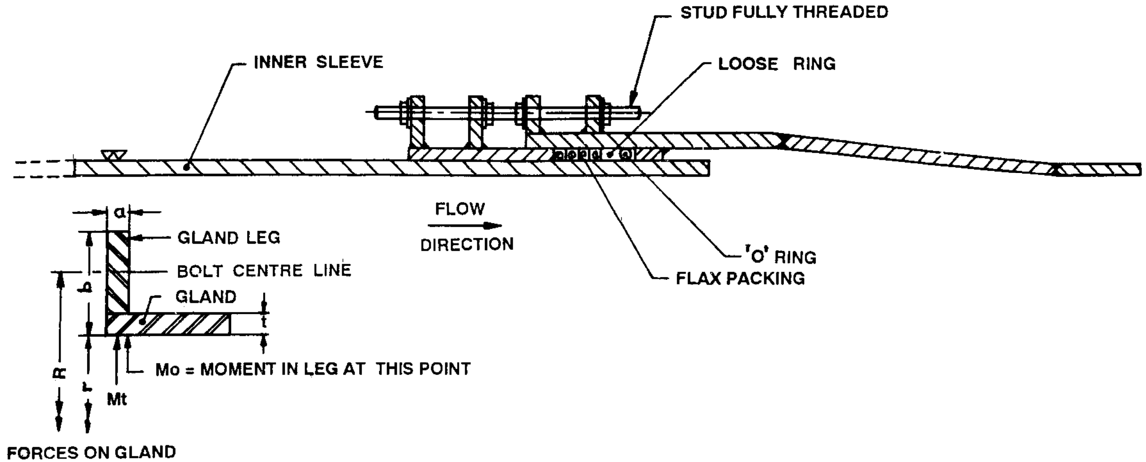
$$\text{Total bolt force} = \frac{M A Y_0}{f_s} \qquad \text{......... (xi)}$$

where

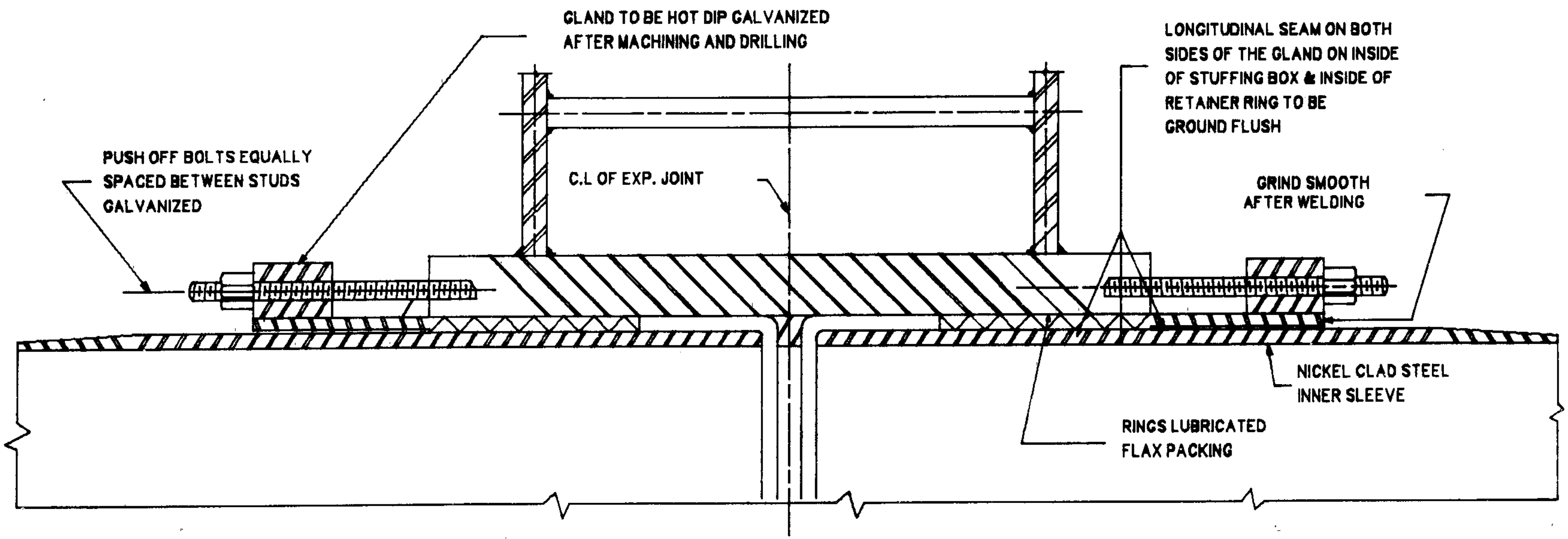
P = internal pressure in the pipe in N/mm² and

P_2 = pressure mobilized between packing and inner sleeve by bolt pressure P_1 in N/mm².

$$P_1 = \frac{\text{Total bolt force}}{\text{Area of packing}} = \frac{M A Y_0}{f_s \pi D' W} \qquad \text{......... (xii)}$$



4A Single Sleeve Type



4B Double Sleeve Type

FIG. 4 SLEEVE TYPE EXPANSION JOINT

where

M = number of bolts,

A = root area of bolt in /mm^2,

Y_0 = yield point of the material in N/mm^2,

f_s = factor of safety,

D' = diameter to the centre of packing rings in mm,

W = width of packing ring in mm, and

μ = poisson's ratio.

The spacing of bolt is generally kept at 250 mm to 300 mm centre to centre. The packing should consist of 4 to 8 rings of square, lubricated, braided long fibre flax rings, the number depending upon the internal pressure. The size of the packing may vary from 16 mm to 32 mm depending upon the size of expansion joint.

6.3.1.2 *Design of inner sleeve*

Length of sleeve (L') should not be less than value given by the formula:

$$L' = \frac{2\pi}{\lambda}$$

where there is no water inside the penstock, then there will be only external pressure P_2. The actual hoop stress will be less than (P_2 R_1)/t since it is loaded for shorter length. It may be taken as

$$\sigma_1 = \frac{P_2 R_1}{t}\left[1 - e^{-\lambda L/2} \operatorname{Cos}\frac{\lambda L}{2}\right]$$

where

L = actual length in mm over which the load is applied,

λ = plate constant = $\sqrt[4]{\dfrac{3(1-\mu^2)}{R_1^2 t^2}}$

$= \dfrac{1.285}{\sqrt{R_1 t}}$ for $\mu = 0.3$

R_1 = $D/2$, and

t = thickness of leg of gland in mm.

This uniformly distributed load over short length would give rise to additional axial moment M and axial bending stress as given below :

$$M = \frac{P_2}{2\lambda^2}\left[e^{-\lambda L/2} \sin\frac{\lambda L}{2}\right], \text{ and } \sigma_2 = \frac{6M}{t^2}$$

These two stresses will be acting simultaneously. This bending moment will die out after a certain distance and so also the hoop stress. The combined stress σ is given by:

$$\sigma = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_1 \sigma_2}$$

A factor of safety of 2 to 3 is normally adopted to arrive at allowable working stress.

6.3.1.3 *Design of gland*

The gland flange should be able to resist the bending moment developed by the gland bolt forces. The gland should be designed such that the gland bolts yield before the gland.

$\lambda = \dfrac{1.285}{rt}$ where r = inside radius of gland in mm

F = bolt force per mm of inside circumference

$= \dfrac{M A Y_0}{2\pi r}$

M_t = applied moment per mm of inside circumference

$= F [R - (r + t/2)]$

$$M_0 = \frac{M_t}{1 + \frac{\lambda a}{2} + \frac{1.151\,3}{\lambda r}\left(\frac{a}{t}\right)^3 \log_{10}\left(1 - \frac{b}{r}\right)}$$

σ_b = bending stress in leg

$= \pm \dfrac{6 M_0}{t^2}$ N/mm^2

σ_c = compressive stress in leg

$= - \dfrac{F}{t}$ N/mm^2

Total stress in leg = $\sigma_b + \sigma_c$ (should be less than yield point with allowable factor of safety).

6.3.2 *Bellows Type Expansion Joint*

Bellows type of expansion joints are generally used for low pressure pipe lines and for pipes of moderate diameters and for slight movements. There is no sliding surface in this joint and the expansion is obtained by the flexibility of the thin plates forming the joint. The flexible diaphragm will either stretch or compress in the direction of pipe axis to allow for the longitudinal movement of the pipe. Such type of joints are not suitable for high heads above 15 m to 20 m because the thickness of diaphragm required to withstand the internal pressure would be too stiff to allow for any flexibility of expansion. A typical bellows type of joint is shown in Fig. 5.

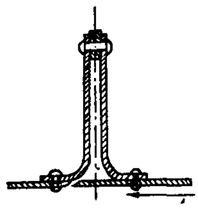


FIG.5 BELLOW TYPE OF JOINTS (TYP.)

6.4 Dresser Couplings

Couplings are used in the installation of steel pipes of moderate diameter, say upto 1.8 m to 2.5 m, for joining pipe lengths in the field. They are flexible for movement of pipes and allow for about 10 mm movement and 3 degrees to 4 degrees deflection at each joint. Since the components are simple, they permit speedy installation under different site conditions.

Wherever couplings are provided expansion joints are eliminated. They are specially suitable where it is desireable to eliminate field welding. A typical dresser coupling is shown in Fig. 6.

The joint consists of one cylindrical steel middle ring, two follower rings on either side, two resilient gaskets of special compound and a set of high strength steel track head bolts. The middle ring has a conical flare at each end to receive the wedge portion of the gasket and the follower rings confine to the outer shape of the gaskets. The bolts are tightened so as to draw the follower rings together, thereby compressing the gaskets between the middle ring and pipe surface, to effect a flexible and leakproof seal.

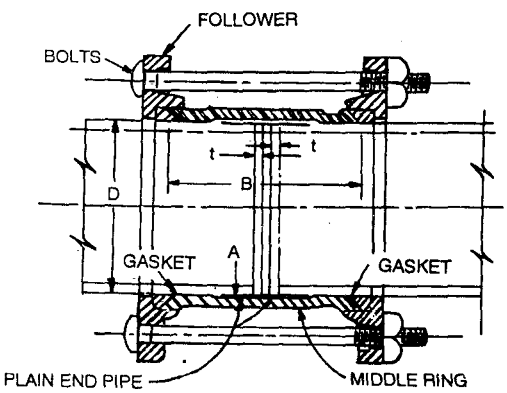


FIG.6 DRESSER COUPLING

7 MANHOLES

7.1 General

Manholes are provided in the course of the penstock length to provide access to the pipe interior for inspection, maintenance and repair.

7.2 The normal diameter of manholes is 500 mm. Typical details are shown in Fig.7. Manholes are generally located at intervals of 120-150 metres. For convenient entrance, exit manholes on the penstock may be located on the top surface or lower left or right surface along the circumference of the penstock.

7.3 The manhole, in general, consists of a circular nozzle head, or wall, at the opening of the pipe, with a cover plate fitted to it by bolts. Sealing gaskets are provided between nozzle head and cover plate to prevent leakage. The nozzle head, cover plates and bolts should be designed to withstand the internal water pressure head in the penstock at the position of the manhole.

7.4 The pipe should be reinforced around the manhole by providing extra reinforcing plate adjacent to nozzle head. Sectional area of reinforcement should be at least 5 percent to 10 percent greater than the sectional area of the pipe shell.

8 BULKHEADS

8.1 General

Bulkheads are required for the purpose of hydrostatic pressure testing of individual bends, after fabrication, and sections or whole of steel penstock and expansion joints, before commissioning. Bulkheads are also provided whenever the penstocks are to be closed for temporary periods, as in phased construction.

8.2 The shapes of the test heads generally adopted are hemispherical, semi-ellipsoidal or standard dished flange ends as shown in Fig. 8.

8.3 The test heads and bulkheads should be designed to withstand the test pressure of the pipe section.

8.4 The bulkheads should be fabricated out of the same material as used in the penstock.

8.5 For the design of shape, size and connection details of bulkheads *see* IS 2825 : 1969.

9 AIR VENTS AND AIR VALVES

9.1 General

These are provided on the immediate downstream side of the control gate or valve to facilitate connection with the atmosphere.

Air inlets serve the purpose of admitting air into the pipes when the control gate or valve is closed and the penstock is drained, thus avoiding collapse of the pipe due to vacuum excessive negative pressure. Similarly, when the penstock is being filled up, these vents allow proper escape of air from the pipes.

9.2 The factors governing the size of the vents are length, diameter, thickness, head of water, and discharge in the penstock and strength of the penstock under external pressure.

9.3 Size of the air vent may be determined by the following formula:

$$F = \frac{Q\sqrt{S}}{750\,000\,C}\left(\frac{d}{t}\right)^{3/2}$$

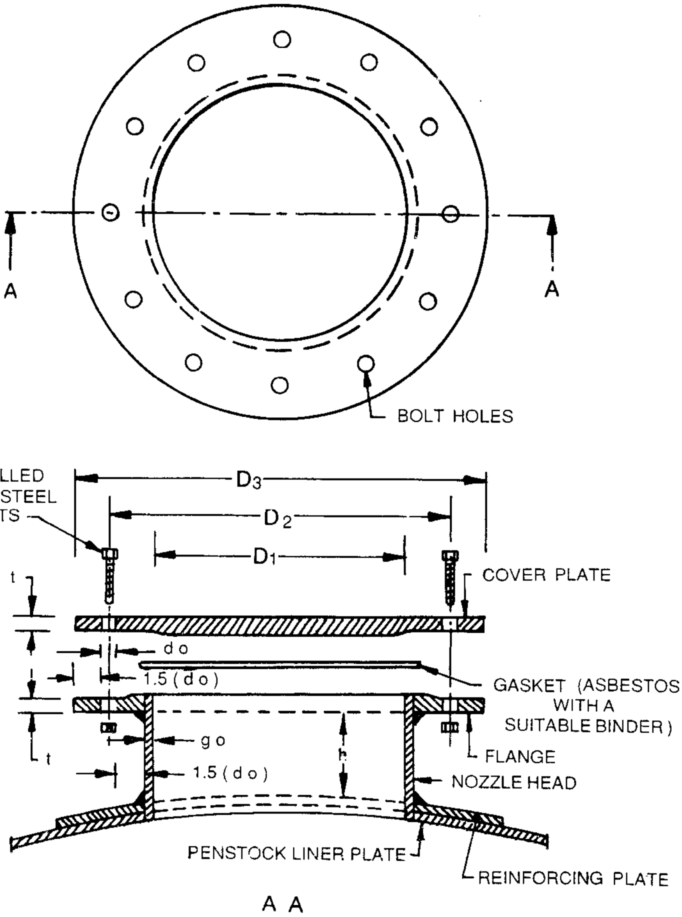


FIG. 7 MAN HOLE DETAILS

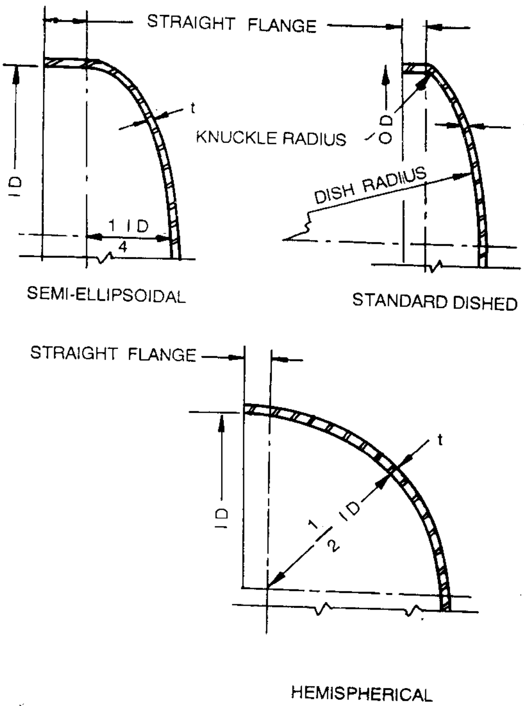


FIG. 8 BULK HEAD

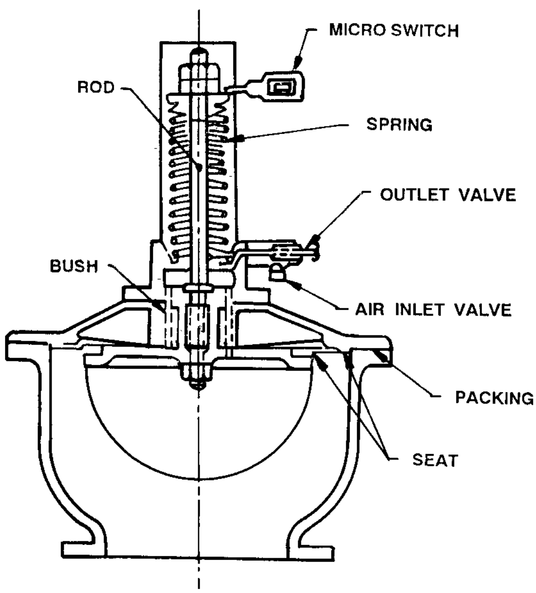


FIG. 9 REPRESENTATIVE TYPE OF AIR VALVE

where

F = area of air inlet in m^2,

Q = flow of air through inlet in m^3/s,

S = factor of safety against collapse of pipe,

C = co-efficient of discharge through airvent (generally 0.6),

d = diameter of steel pipe in mm, and

t = thickness of steel pipe in mm.

9.4 Air valves are subject to great impact during closing or opening. Therefore, their construction should be capable of withstanding such impact. A typical air valve is shown in Fig. 9.

9.5 The minimum sectional area of the air valve may be determined by the following equation:

$$A = \frac{Q}{C\sqrt{2g\frac{\Delta_P}{\lambda_a}}}$$

where

A = maximum flow sectional area in m^2,

Q = maximum water flow in pipe in m^3/s,

Δ_p = difference between allowance pressure in t/m^3,

γ_a = air density in t/m^3 (generally 0.001 226 t/m^3),

g = acceleration due to gravity in m/s^2, and

C = flow co-efficient (generally 0.6).

9.6 In order to avoid risk in the event of failure of air valves, it is desirable to provide two or more redudant air valves, so that minor malfunction of air valve will not cause serious damage.

10 MISCELLANEOUS PENSTOCK ACCESSORIES

10.1 Piezometric Connections

Piezometric connections are provided in the penstock pipes to facilitate connections to pressure gauges located in the control room. Normally these piezometric connections are provided in the straight length of penstock away from bends and branches and near the vicinity of the power house. They are provided in groups of four, equally spaced around the periphery of the pipe section. From each group of these connections the piezometric line is connected to a pressure gauge. Details of a typical piezometric connection are shown in Fig. 10.

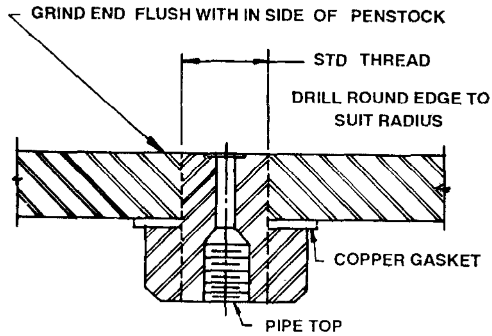


FIG. 10 PIEZOMETRIC CONNECTION

10.2 Flanged Connections

Flanged connections are provided for connecting the penstock with other equipment like valves, expansion joints, turbine scroll case, etc. The type and the design of the flanges shall be made to suit the connecting flanges of the equipment to which the penstock is to be connected. Welding neck type, slip on type and plate type flange connections are generally adopted. Generally, the welding neck type is of forged steel and is used for high heads and pipes of large diameter while the other types are used for medium and low heads and with pipes of smaller diameter. Design of flanged connections shall be done according to IS 2825 : 1969.

10.3 Filling Connections

Intake nozzles are provided in the penstock at suitable locations for connection with filling lines, in order to allow slow filling of penstock during initial filling of the water conductor system. Normally these intake nozzle openings are provided at the horizontal centre of pipes, at the upstream end of penstock. It is preferable to provide this connection on the downstream side of the penstock gate so that filling can be effected under submerged conditions. These filling lines are connected with the reservoir on the other end and provided with proper control valves. These lines should be of sufficient capacity to complete the filling of entire length of penstock within a reasonable time. Design of filling connection should be done according to IS 2825 : 1969.

10.4 Drainage Connections

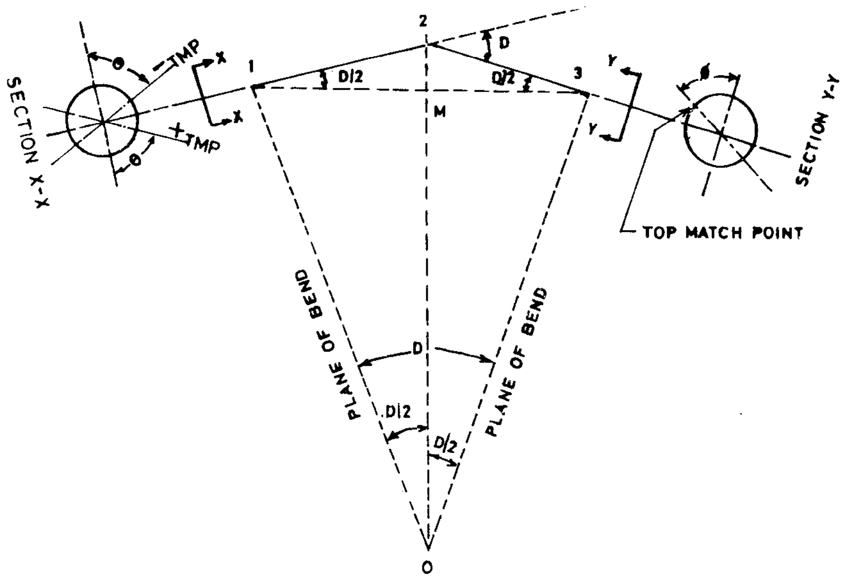
Drainage connections are required to be provided for draining of the penstock whenever the penstock is to be inspected for maintenance and repairs. Drainage nozzles are located at the bottom most reach of the penstock at the lowest point of the pipe with proper grating, flush with the inner surface of the pipe. The drainage lines are normally connected to the draft tube of the turbine.

10.5 Closing Pieces

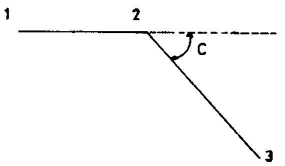
Small unavoidable errors might occur in the penstock system due to errors in the process of fabrication or erection at site or due to discrepancies between theoretical calculations and actual laying of pipe lengths at site, or due to shrinkage of welded joints. In order to permit the final field adjustments and to obtain perfect assembly of the pipe line system a make-up piece of pipe length called closing piece is often provided. These closing pieces should be fabricated with an extra length which is cut to size at site, after erection of entire penstock. Normally, these pipes are fitted either at the connection to the valves or near expansion joints or near turbine scroll case. Design of closing pieces should be done according to IS 11639 (Part 1) : 1986.

ANNEX A

(*Clause* 3.3)



DEVELOPED PLAN



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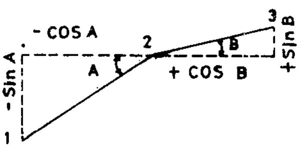

PROFILE

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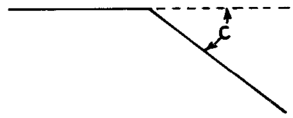

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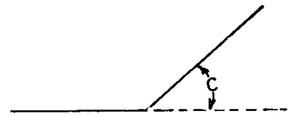

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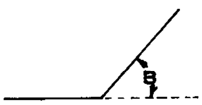

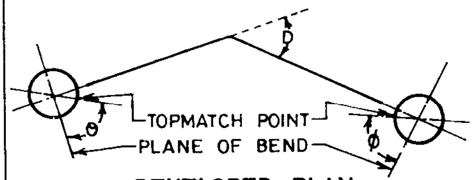

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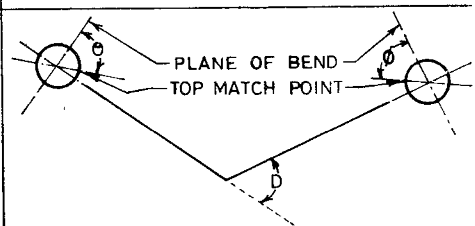

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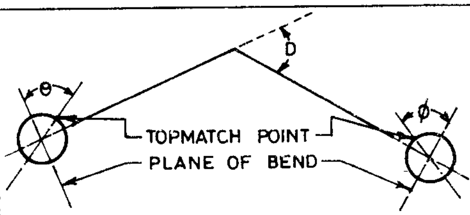

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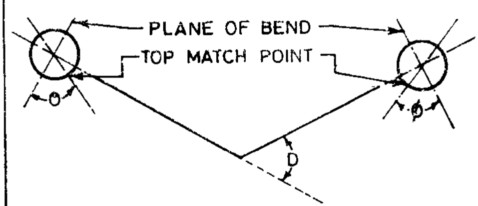

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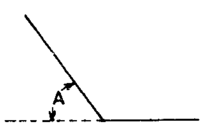

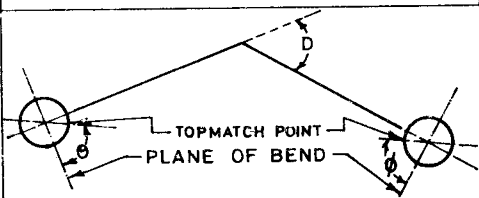

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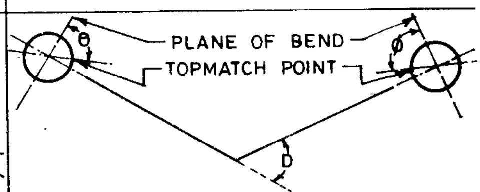

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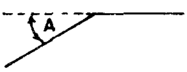

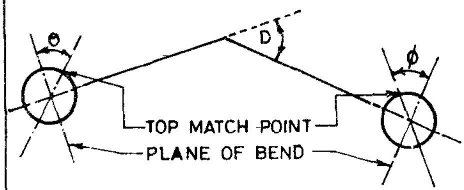

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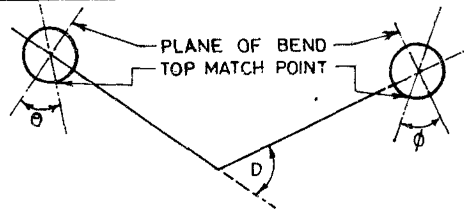

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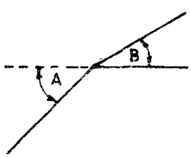

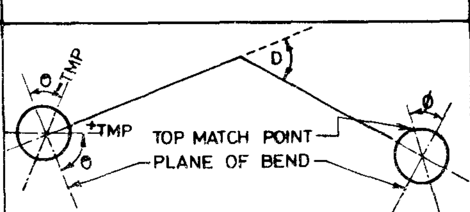

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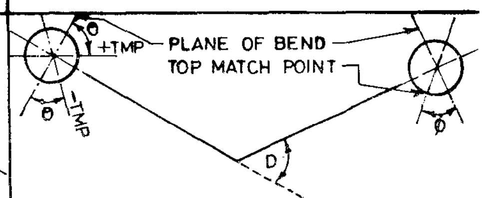

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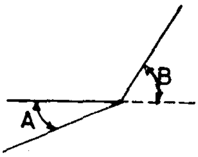

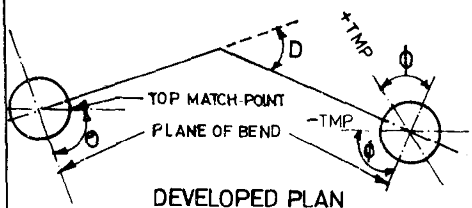

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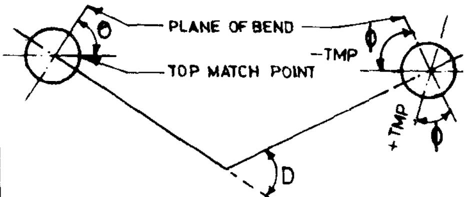

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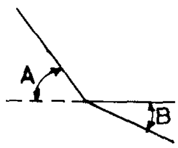

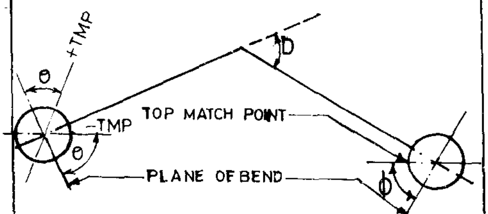

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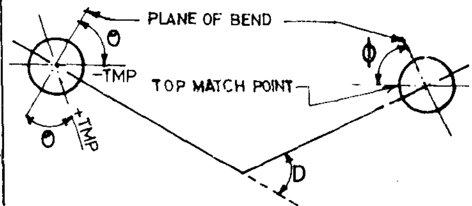

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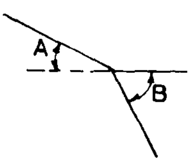

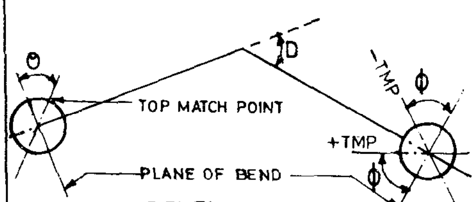

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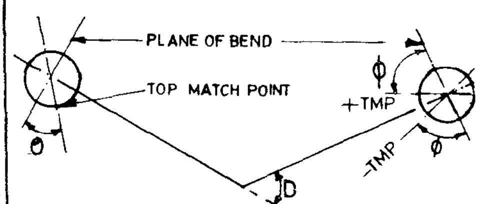

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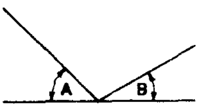

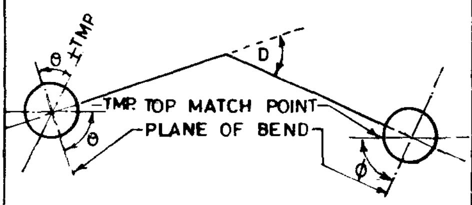

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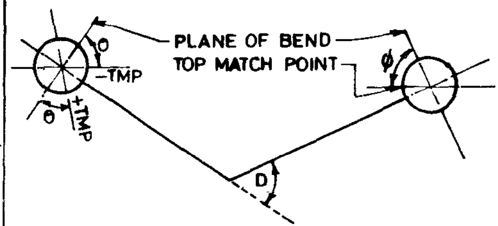

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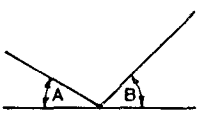

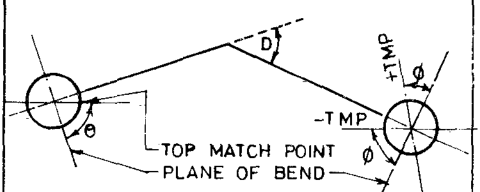

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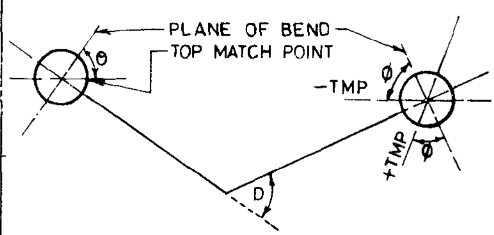

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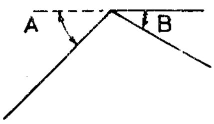

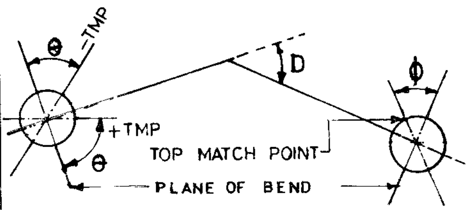

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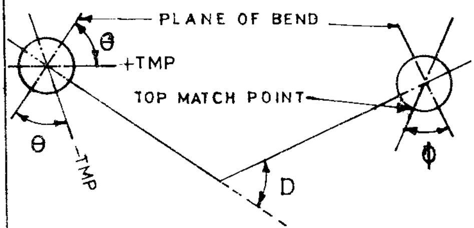

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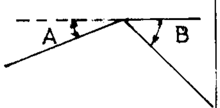

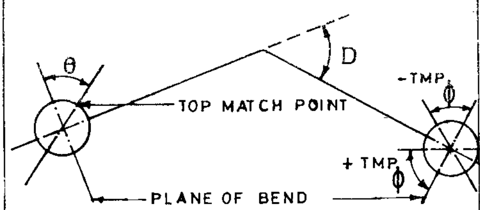

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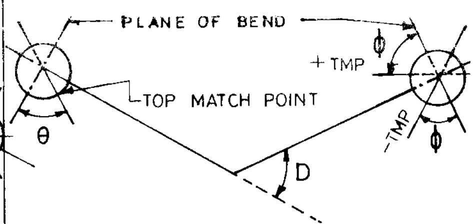

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This Indian Standard has been developed from Doc No. RVD 14 (20).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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AMENDMENT NO. 1 MAY 2002

TO

IS 11639 (PART 3) : 1996 STRUCTURAL DESIGN OF PENSTOCK — CRITERIA

PART 3 SPECIALS FOR PENSTOCKS

(*Page* 7, *clause* **6.3.1.2**):

a) Substitute 't = thickness of the inner sleeve in mm' *for* 't = thickness of leg of gland in mm'

b) Insert the following:
D = inside diameter of penstock shell or inner sleeve'.

(*Page* 7, *clause* **6.3.1.3**):

a) Substitute 't_1' *for* 't' wherever occuring in the clause and insert 't_1' = thickness of leg of gland in mm'.

b) Substitute:

'$\lambda = \dfrac{1.285}{\sqrt{rt_1}}$' *for* '$\lambda = \dfrac{1.285}{rt}$'

c) Substitute:

$$M_o = \frac{M_t}{\dfrac{1+\lambda a}{2} + \dfrac{1.151\,3}{\lambda r}\left(\dfrac{a}{t_1}\right)^3 \log_{10}\left(1+\dfrac{b}{r}\right)}$$

for

$$M_o = \frac{M_t}{1 + \dfrac{\lambda a}{2} + \dfrac{1.151\,3}{\lambda r}\left(\dfrac{a}{t}\right)^3 \log_{10}\left(1-\dfrac{b}{r}\right)}$$

(WRD 14)

Reprography Unit, BIS, New Delhi, India

AMENDMENT NO. 3 DECEMBER 2006
TO
IS 11639 (PART 3) : 1996 STRUCTURAL DESIGN OF PENSTOCK — CRITERIA

[*Page* 7, *clasue* **6.3.1.3** (*see also Amendment No.* 1)] — Substitute:

$$M_0 = \frac{M_t}{1 + \frac{\lambda_a}{2} + \frac{1.1513}{\lambda_r}\left(\frac{a}{t_1}\right)^3 \log 10\left(1 + \frac{b}{r}\right)}$$

for

$$M_0 = \frac{M_t}{\frac{1 + \lambda_a}{2} + \frac{1.1513}{\lambda_r}\left(\frac{a}{t_1}\right)^3 \log 10\left(1 + \frac{b}{r}\right)}$$

(WRD 14)